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Influence analysis of Arctic tide gauges using leverages

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Introduction

Reconstruction of sea level in the Arctic Ocean is a major challenge, owing to the sparsity of data available. To obtain a reconstruction covering 1950 to today, we adapt the EOF-based model by Church et al. (2004), using a calibration period based on the Drakkar ocean model (as a surrogate for satellite altimetry, using only data from the altimetry era), and using PSMSL tide gauge records to force the model.

The *leverage* of each tide gauge is a statistical measure of its influence on the result. This way, we can readily identify possible outliers among the tide gauge records in a procedural, objective way.

Model

We adapt the model by Church et al. (2004), which is in turn based on the model described by Kaplan et al. (1997), i.e. minimizing the cost function.

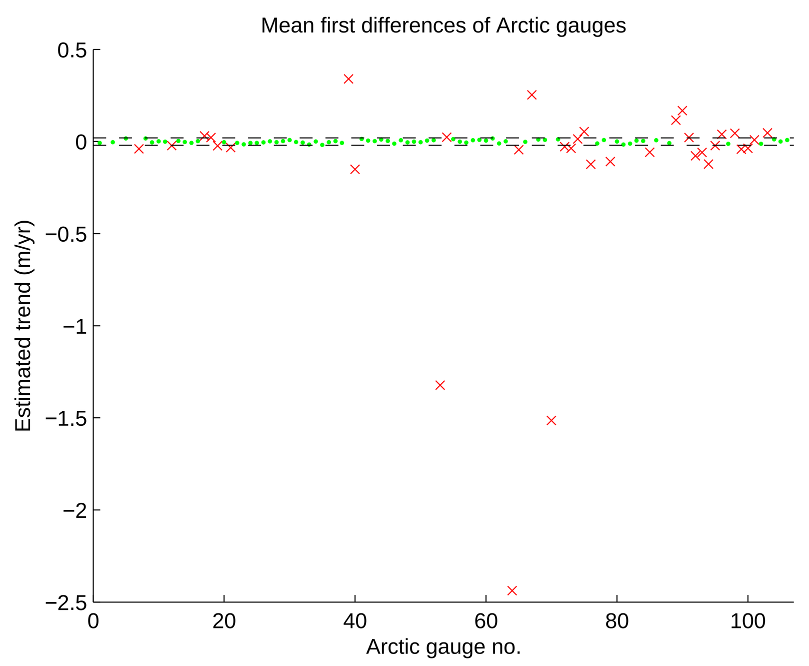
$$(\mathbf{HE}\boldsymbol{\alpha} - \mathbf{G})^{\mathsf{T}} \mathbf{R}^{-1} (\mathbf{HE}\boldsymbol{\alpha} - \mathbf{G}) + \boldsymbol{\alpha}^{\mathsf{T}} \boldsymbol{\Lambda}^{-1} \boldsymbol{\alpha}$$

where $\mathbf{E}$ are the retained eigenfunctions from a calibration period, $\mathbf{G}$ are the tide gauge records, $\mathbf{H}$ an indicator matrix, $\mathbf{R}$ describes the error covariance, and $\boldsymbol{\Lambda}$ contains the retained eigenvalues. We solve for $\boldsymbol{\alpha}$, giving coefficients for the eigenfunctions at each time step. To capture any overall trend in the data, the eigenfunction basis is augmented with an "EOF0" (a spatially uniform pattern).

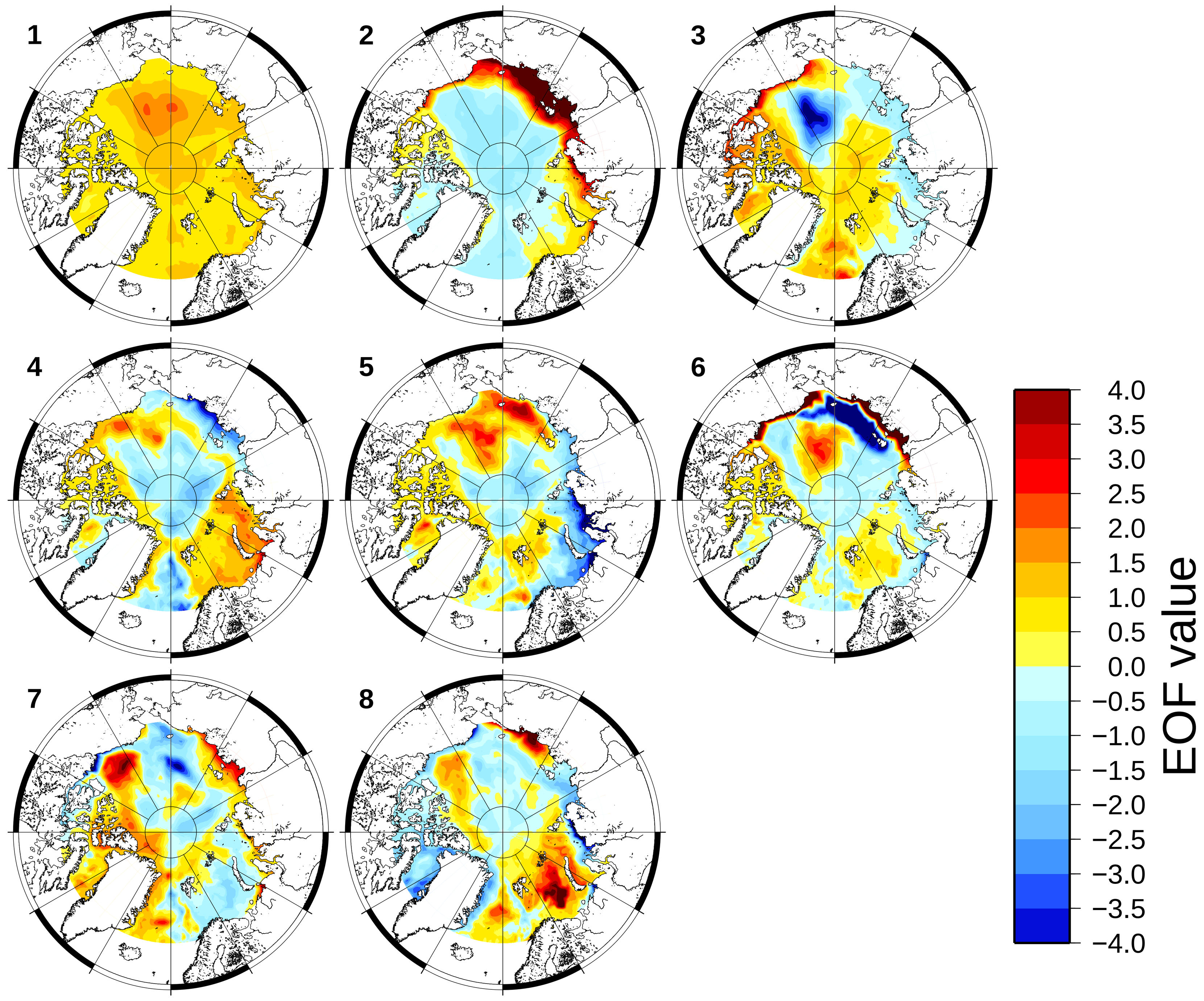
Data

- Only data above 68°N
- Monthly Drakkar ocean model data (sea level height, monthly, 1993–2007)
- Monthly PSMSL tide gauge data (monthly, 1950–2010)
- GIA and IB corrections applied to tide gauge data (Peltier ICE-5G and HadSLP2, respectively)

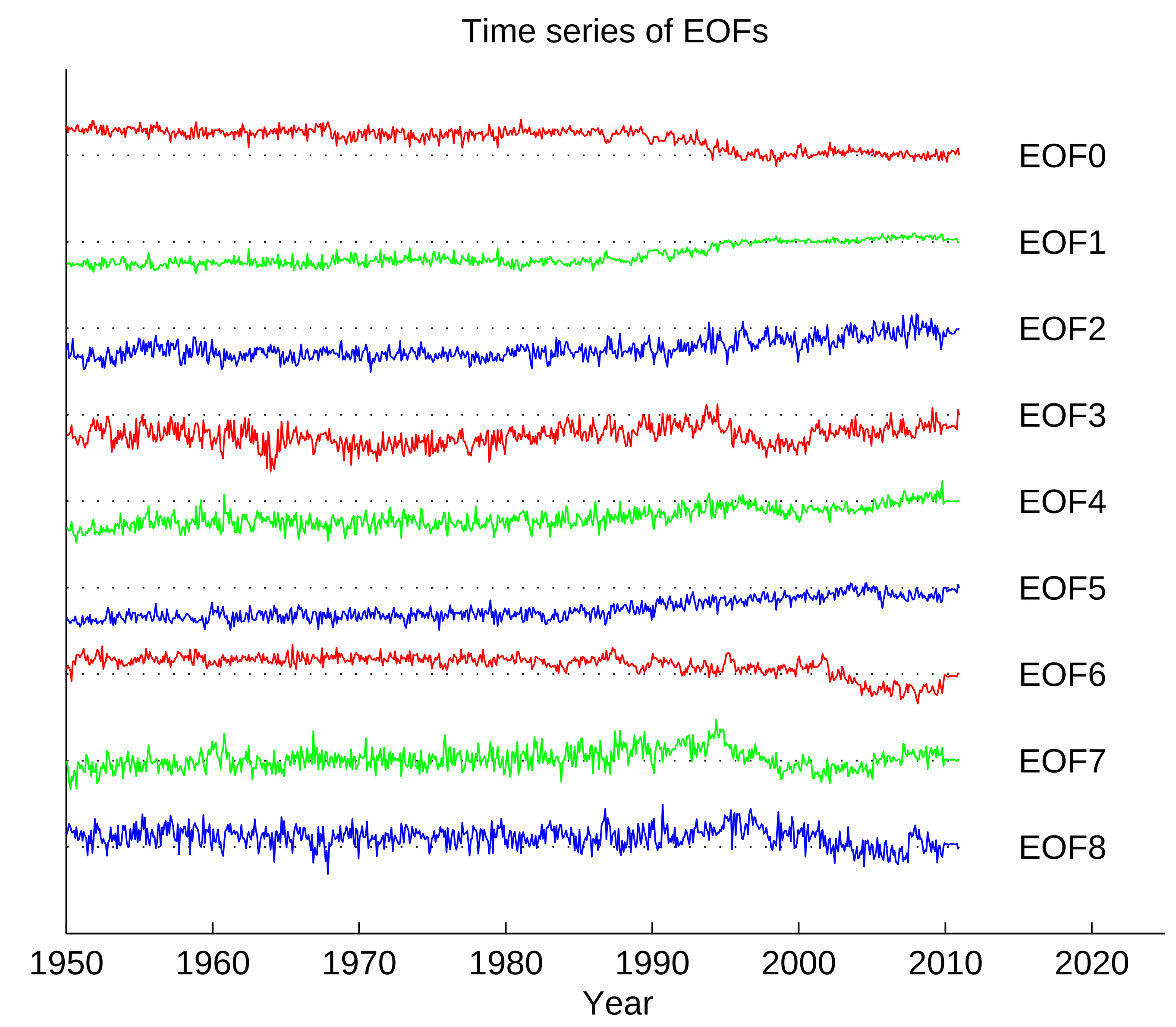
In order to obtain a good reconstruction, we find that it is crucial to perform an empirical pre-culling (based on rough trend estimates) of the gauges.



EOFs

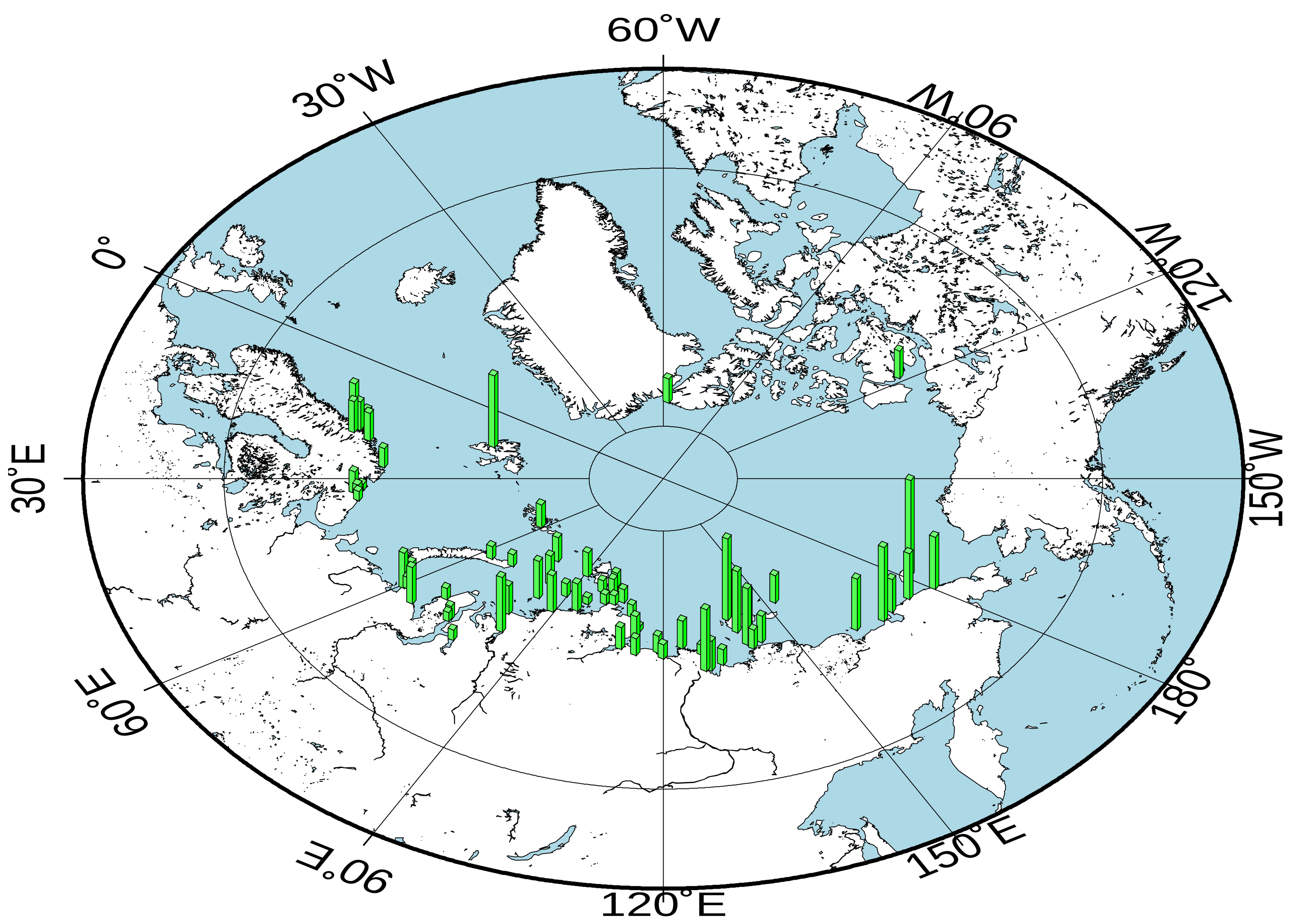


Note the near-uniform appearance of EOF1, which may cause the augmentation with "EOF0" may thus be superfluous; the corresponding solution time series are also strongly correlated.



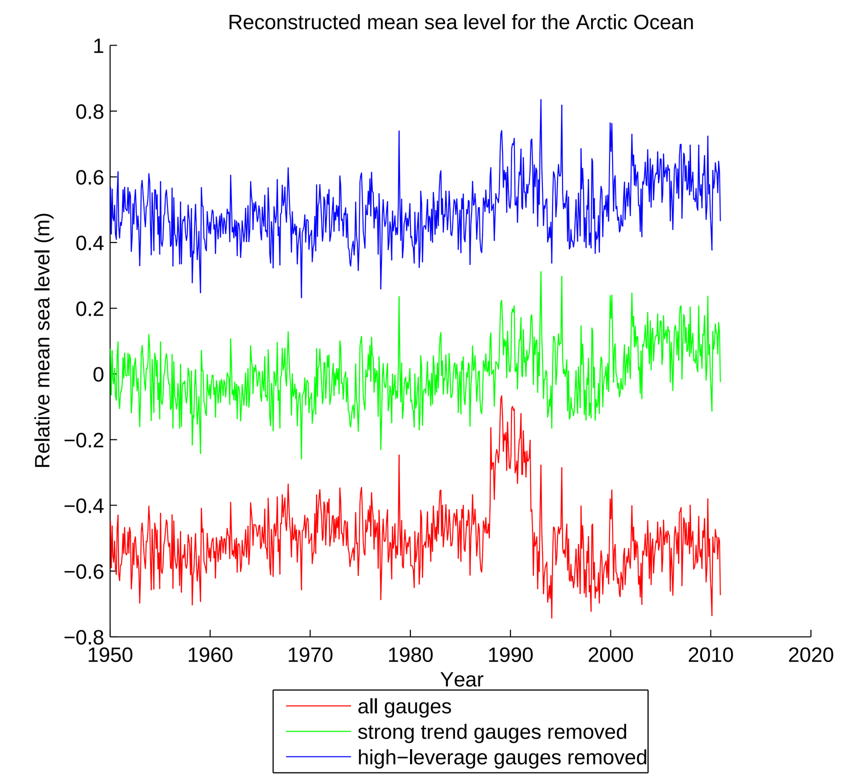
Leverages

The computed leverages are illustrated in the figure below. Highly influential gauges can be identified using empirical criteria, e.g. more than three times the mean of all leverages.



Of the tide gauges above 68°N, we identify two gauges in the Russian sector as having particularly high leverage and omit them from the reconstruction.

The reconstructed mean sea level with all Arctic gauges, all gauges surviving empirical pre-culling, and those additionally having "moderate" leverage is shown on the right.



Conclusions

- Leverage useful to indicate trend mismatches (GIA inaccuracies?)
- Reasonable agreement with other sea level studies of the area